Propagation Measurement in IMT-2000 Band in Malaysia Environment

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Abstract:

The mobile channel is one of the factors, which limits the performance of the wireless communication system. The radio path (the path between the transmitter and receiver) can vary from a simple line-of-sight (LOS) to one that is blocked by the mountains. The performance of wireless channel is hard to predict compared to wired channel. A propagation measurement had been carried out in conjunction with the W-CDMA (Wideband Code Division Multiple Access) Field Trial in Malaysia. The main objective of the measurement is to determine the performance of the W-CDMA system in Malaysia environment. The system performance is evaluated base on the Bit Error Rate (BER). The pathloss exponent (propagation power law) also be investigated. The BER measurement was based on the BER on the downlink of BTS (Base Tranceiver System).

Keyword:
W-CDMA, IMT2000, BER.

1. Introduction

The mechanisms behind electromagnetic wave propagation are diverse, but can generally be attributed to reflection, diffraction and scattering. The diffraction can easily found in urban area where there is no LOS and the present of high rise building. With the reflection from various objects, the electromagnetic waves travel along different paths of varying lengths. The summation of all the signals from different paths will cause multipath fading at specific location.

Large-scale is one type of propagation models used to predict the signal strength at particular location.[1] The large-scale propagation models are used in estimating the coverage area of a transmitter. It characterizes signal strength over large T-R separation distance.

The performance of the WCDMA system was evaluated by its BER. The BER of the system had been measured in two different environment, ie. rural and suburban area.

2. System Setup

The receiving equipment's setup for the field measurement in Sungai Besi Area is shown in Fig.1 . All the equipment is loaded in a testing vehicle with batteries as source of power for all the test equipment. Fig. 2 shows the equipment setup for BER measurement

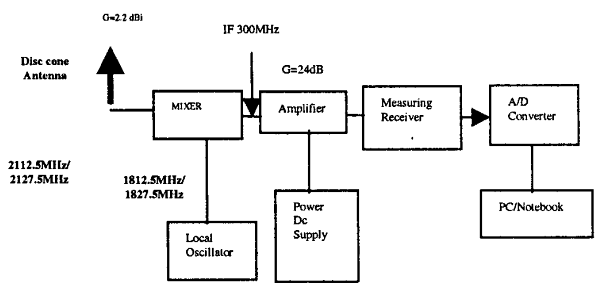

Fig. 1 : Equipment Setup Used For The Field Measurement In Sungai Besi Area

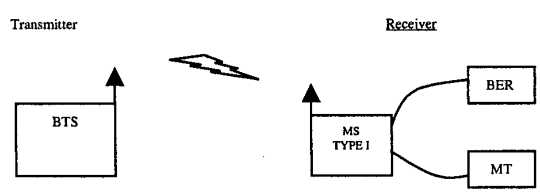

Fig. 2 : BER Measurement Equipment Setup

3. Test Procedure For Coverage Measurement

The coverage measurement for the W-CDMA system is explained below. The transmitter used for this measurement is the *W-CDMA Base Transceiver System (BTS)* provided by *NTT DoCoMo.* The location of the transmitter is at Maxis TOC, Bukit Jalil. During the measurement, *Macro* program setups the BTS to transmit carrier frequencies at 2112.5 MHz and 2127.5MHz (for *sector one* and *sector two* respectively). The transmitted power is 43dBm. The site map in Fig 3 shows the location of BTS in Bukit Jalil. The receiver setup used in the measurement is shown in Fig 1.

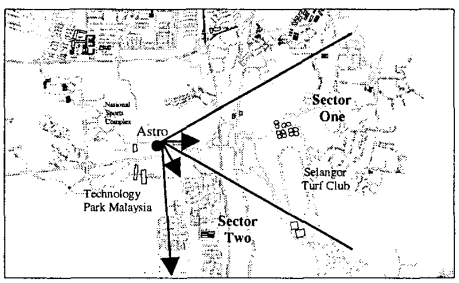

Fig. 3 : Site Map For W-CDMA Field Trial

The receiving antenna used in the measurement is a cone disc type. The gain is 2.2dBi. The receiving RF signal is down converted by using mixer and local Oscillator. The IF frequency is 300MHz. The IF signal goes through an amplifier to get a better signal reception. The gain of the amplifier is 24dB. The IF signal is measured by *field strength meter.* The measured data (field strength) is going through an A/D Converter (Data Acquisition Card) for analog to digital conversion process. Finally, all the digital data is stored in PC's hard disk

Before the measurement being carried out, the receiver and data logging system (A/D Converter) had been calibrated. From the calibration, a lookup table has been produced. This table gives the relationship between the data collected by using *data acquisition card* (in dc value) and the signal received at the input (dBm) of the *field strength meter* (receiver). The calibrated data is used for DC to dBm conversion in data analysis.

There are about 310 data collection locations within the coverage area of 3km radius. The locations are randomly chosen and depended on the accessibility of the testing vehicle to particular location.

For the coverage measurement, the receiving antenna is fixed on top of testing vehicle. At a data collection location, the testing vehicle is being moved slowly before data being collected. When the vehicle is in constant motion, computer controlled data collection program is executed. The data collection program is collecting signal strength data at receiver side via data acquisition card. A total of 3000 samples are collected at a particular location. The measuring period are 30 seconds. The total displacement distance of the vehicle during the measurement are about 5m~10m. By moving the testing vehicle slowly for about 5m~10m, the fast fading effect is eliminated from the data collected.[1] Which means that the data collected only shows the effect from large-scale fading. The same process is repeated at others location.

4. Test Procedure for BER Measurement

For the BER Measurement, Pseudo Random Bit Sequence (PRBS) is used as test signal to eliminate the synchronization problems between transmitting and receiving side. PN9 and PN15 are two most common PRBS signals used in mobile phones. PN9 is a 511-bit(2^9-1) sequence, and similarly PN15 is a 32,767-bit (2^{15}-1) sequence. PRBS are unique because a 9 or 15-bit sequence never repeats during the entire corresponding 511 or 32767-bit sequence.[2] As a result, the PRBS test signal has the transmission characteristic of a randomly created signal. However, unlike the randomly created signals, all subsequent bit sequences can be determined from any 9-bit sequence for PN9 or 15-bit sequence for PN15.

This unique property makes it possible to reconstruct the subsequent portion of the 511- or 32,767-bit. Subsequently received bits are then compared with the reconstructed bit stream. This makes the test done without directly compare the received and transmitted bits, hence eliminates the synchronization between the received and reference bit streams.

The BER tester must receive and correctly demodulate at least one 9 or 15-bit sequence in order to reconstruct the entire 511 or 32,767-bit sequence. Therefore, a system with an error rate of over 11% (1/9) for PN9 and 6.7%(1/15) for PN15 cannot start a measurement because bit-stream reconstruction is impossible.

3.1 Forward-link BER Measurement

For the W-CDMA system provided by NTTDoCoMo, there are two RTP (Return point) in MS TYPE I to investigate wrong condition/abnormal connection , ie RTP and RTP2.[3] There are three types of Logical channels which can be returned, ie DTCH, SDCCH and UPCH. The PN Return mode used in the measurement is shown in Fig 4. The PN Insert mode used in the measurement is *mode 53.* The PN insertion mode 53 support 32,64 and 128ksps for DTCH.

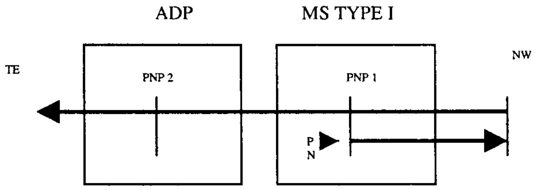

Fig. 4 : PN Return Mode 53

The interface condition between MS Type 1 and BER counter is as follows:

- Signal level....................5V TTL
- Clock ....Burst wave at 10ms unit based on 768kHz
- Timing ....Data change at the rise clock
- No data transmission section ......Clock stop

Possible conditions for measurement:

- Channel .... DTCH (single code) only
- Symbol rate 32,64,128ksps

The picking point of the test signal for BER measurement is done after "CRC check" and "Tail bit discard". The PN signal is picked from "X" in Fig. 5.

CRC	X	Tail
13 bit	X bit	8 bit

Fig. 5 : Test signal picking point

At the measurement time, the system setup can only perform the forward-link [link from BTS to Mobile Station TYPE I (MS TYPE I)] BER measurement. The traffic channel used for the measurement is the *DTCH (Dedicated Traffic Channel).* The system can support symbol rate of 32ksps , 64ksps and 128ksps. The symbol rate used in the measurement is 128ksps. The BTS settings are shown in Table 1.

The BTS transmit BCCH and DTCH by commands given by its MT (Maintenance Tools). The MS TYPE I detects BCCH (Perch channel) transmitted by BTS. When the Perch channel successfully be detected, the MS TYPE I setups DTCH by commands from its MT. After DTCH be successfully set upped, the MS TYPE I outputs clock signal and PN signal to DTA (Digital Transmission Analyzer) via coaxial cables. After the DTA receives the clock and PN signal, the BER test can be carry out.

Table 1 : BTS Setup during propagation measurement

Parameter	Specification
Carrier Frequency Downlink:	 2117.5MHz
Chip Rate	4.096Mcps
Bandwidth	5MHz
Symbol Rate	16-1024ksps
Spreading Code Short Long	 Orthogonal Gold Code Gold Code Family
Modulation Data: Spreading:	 QPSK QPSK
Diversity	RAKE and Antenna
TX Power	43dBm
Antenna Gain	18dBi
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The total numbers of data collection locations are 105 in Sector 2 and 65 locations in Sector 1. The locations are chosen along several paths consisting of straight lines radiating away from the cell site (BTS). The closest point being a distance of 0.5km from the site while the furthest is 4km. Presumably, all the test points chosen were located well within the coverage of the main lobe of the transmission. Sector 2 is chosen for most of the tests because of the terrain and clutter are more uniform. In *sector two*, the area is mostly covered by residential and commercial buildings. The buildings' height ranges from single story to three stories. There are some high rise buildings in that area. *Sector two* has high density of human made structure. *Sector one* is mostly covered by vegetation and some buildings. The buildings in that area are mostly single and double stories houses. The human structures are less compared to *sector two.*

During the measurement, the testing van is parked at a predefined location. When the testing van is parked properly, the DTA is activated. DTA is set to record the BER for 3 minutes. Besides the BER, others information like Perch channel level, Eb/Io are also recorded.

The BER measurement also was performed in the case of interference. For the interference measurement, sector one is transmitting the same frequency as in sector two but with different PN sequence. BER is measured for all the locations in sector two.

4.0 Results

4.1 Path-loss and coverage analysis

From the data obtained, the path loss exponent (n) for sector one is 2.4 and with a standard deviation of 7.9dB. While for the sector two, the value of n is 3.9 and with standard deviation of 12.4dB. According to the Rec. ITU-R M.1225 [4], for the *Outdoor to Indoor and Pedestrian Test Environment*, the path-loss exponent (path-loss rule) ranges from n=2 to n=6 (R^{-2} to R^{-6}) The Fig. 6 and Fig. 7 show the received signal vs distance for *sector one* and *sector two*.

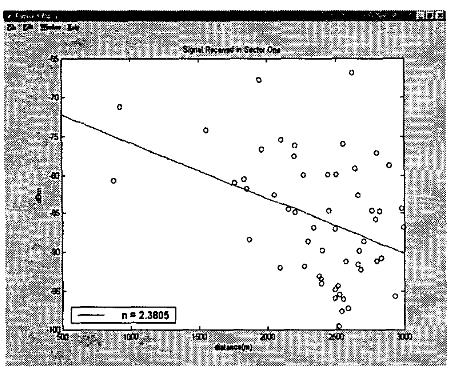

Fig. 6 : Received Signal Strength Vs Distance In Sector One

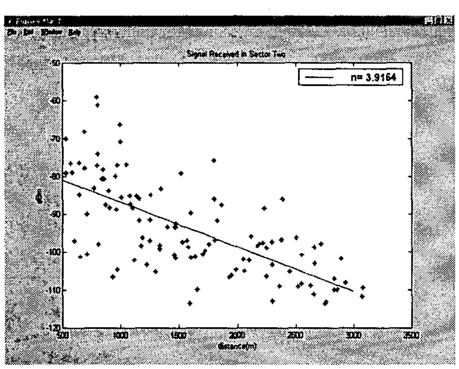

Fig. 7 : Received Signal Strength Vs Distance In Sector Two

The received signal in *sector two* experienced a relative high loss compared to *sector one*. One of the reasons is that the terrain differences between *sector one* and *sector two*. Fig. 8 shows the signal coverage for *sector one* and *sector two*. In Fig. 8, the lines show the signal strength of the received signal measured by receiver during the field measurement.

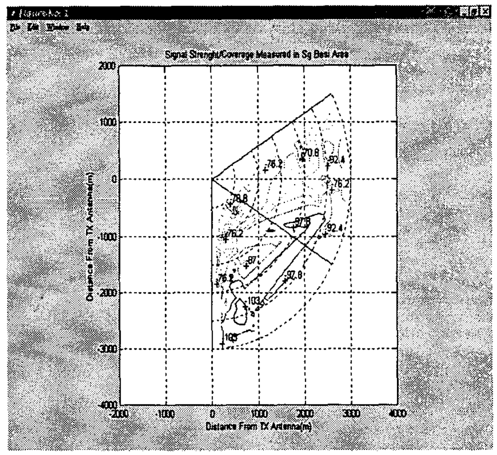

Fig. 8 : Contour Plot For Received Signal Strength In Sector One and Sector Two.

4.2 BER Measurement Results and Analysis

The BER performance for symbol rate of 128ksps in *Sector One* is shown in Fig. 9. The measurement results show that 60% (38 locations) from the total measurement locations having the BER lower than exp-6. While there are 40% (26 locations) show the BER fall in the range of exp-3 to exp-6. The number of measurement location in *Sector One* is 64.

Fig. 10 show the BER performance for *Sector Two*. From the total number of locations, 66.9 %(79) points) show the BER performance well below 10^{-6}. There are 34 points (28.8%) within the range $10^{-3}<x<10^{-6}$. There are only 5(4.2%) points showing the BER more than 10^{-3}, all those points are beyond 3km radius. The total numbers of measurement location are 118.

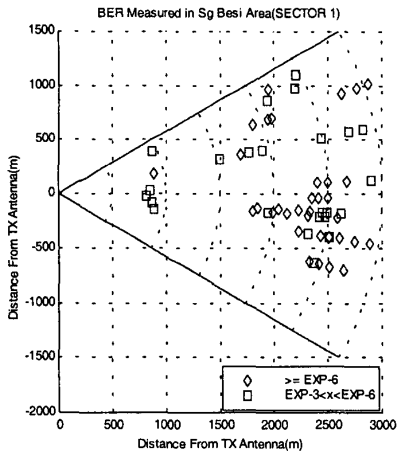

Fig. 9 : BER performance *Sector One*

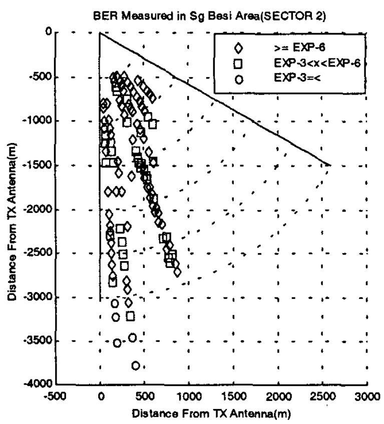

Fig. 10 : BER performance in *Sector Two*

Fig .11 shows the BER performance for the case of interference from other sector. The total numbers of location for this measurement are 106. From the total number of locations, there are 43 locations (40.6%) showing the BER below 10^{-6}. There are 59 locations (55.7%) show BER between $10^{-3}<x<10^{-6}$, where 4 locations (3.8%) show BER above 10^{-3}.

The results show that, with the interference from other sector, the performance of the system experiences degradation. There is a significant increase in the number of location with the BER fall between 10^{-3} and 10^{-6} .

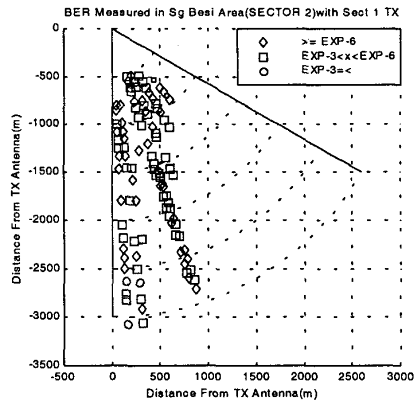

Fig. 11 : BER performance in interference environment

Conclusion

From the static (no movement at MS) measurement results show that there are more that 60% of the total data collected show the BER lower than 10^{-6}. And the rest of the data collected showing BER fall between 10^{-3} to 10^{-6}. From M.1225, ITU-R, requires that all the candidates RTT should give the BER $\leq 10^{-3}$ for voice and $\leq 10^{-6}$ for data application.

From the results show that sector two (suburban area) showing a relatively good BER results compared to sector one (rural) area. One of the reasons is that the W-CDMA system employed RAKE receiver. Where RAKE receiver can improve the performance of W-CDMA through the exploitation of multipath fading.

Reference:

[1] Lee, William C.Y (1992). "Mobile Communication Design Fundamentals." 2nd ed. John Wiley&Son : New York.

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[3] "Specification For W-CDMA Mobile Communication System Experiment" NTT DoCoMo Inc.

[4] Association of Radio Industries and Business (ARIB) IMT-2000 Study Committee (1998). "Japan's Proposal for Candidate Radio Transmission Technology on IMT-2000:W-CDMA."Tokyo: ARIB IMT-2000 Study Committee.

[5] ITU-R(1997) ."Guide Lines For Evaluation of Radio Transmission Technologies For IMT-2000." Recommendation ITU-R M.1225.